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Notes relating to the Physical Geography and Geology of, and the Distribution of Terrestrial Mollusca in certain of the West India Islands.

BY THOMAS BLAND.

(Read before the American Philosophical Society, March 3, 1871.)

In 1861 I published (Ann. Lyc. Nat. Hist., N. Y. VII.) a paper on the Geographical distribution of the genera and species of land shells of the West India Islands, and in 1866 (American Jour. of Conchology, I.) further papers on the same subject. From a study of such distribution, without reference to the Physical Geography or Geology of the Islands, I arrived at the conclusion that they may be divided into the five following provinces or sections, each having a distinct faunal character, viz. :

I. Cuba with the Isle of Pines, Bahamas, and Bermudas.

II. Jamaica.

III. Haiti.

IV. Puerto Rico with Vieque, the Virgin Islands, Sombrero, Anguilla, St. Martin, St. Bartholomew, and St. Croix.

V. The Islands to the south of those last mentioned, to and inclusive of Trinidad.

I remarked that the Islands to the West of Puerto Rico have the greater generic, as well as specific alliance with the North American Continent (Mexico and Central America, of course, included), and those to the East and South, with tropical South America.

Within the last year I have endeavored to learn, if any and what evidence may be gathered from the depth of the sea around, and in the vicinity of the Islands, of their former greater proximity to each other and the adjacent continents, sufficient to account for or throw light on the observed facts of land shell distribution. The result is extremely interesting, and in the main confirmatory of the views above expressed.

The British Admiralty Charts have afforded data, chiefly to the 100 fathom line of soundings only, while recently, through the kindness of Mr. Rawson W. Rawson, Governor in Chief of Barbados and the Windward Islands, I have obtained particulars of the deep sea soundings, taken in the Caribbean sea, especially for Telegraph Cable purposes, by United States and British Naval Officers, which supply information of great value, as I propose in this paper to show. I am also indebted for much information to "The West India Pilot," published by the British Admiralty.

I reserve, for another opportunity, observations on the faunas of the first three of the above mentioned sections, now confining myself to the fourth and fifth, with incidental reference to that of the second. Since the date of my former papers, my knowledge of the species inhabiting the Islands embraced in the latter sections has been largely increased, for which my acknowledgments are due principally to Mr. Robert Swift, of St. Thomas, Dr. Cleve, of the University of Upsala, Governor Rawson, and Mr. R. J. Lechmere Guppy, of Trinidad.

SECTION IV. *Puerto Rico with Vieque, the Virgin Islands, Sombrero, Anguilla, St. Martin, St. Bartholomew, and St. Croix.*

Puerto Rico, Vieque and the Virgin Islands, of which Anegada is the most eastern, stand on one and the same bank, an elevation of which to the extent of somewhat less than 40 fathoms (240 feet) would unite the whole, converting them into one Island. Sombrero is on another bank, about 40 miles from the Virgin bank, and 23 miles from the north end of the Anguilla bank. The depth of the channels which separate the Sombrero bank from the Virgin bank on the west, and the northern end of the Anguilla bank to the east, is not known, but soundings are recorded, at their margins, of 160 fathoms (960 feet) and 190 fathoms (1,140 feet), without bottom.

Anguilla, St. Martin and St. Bartholomew stand on the western edge of another bank of considerable extent. Its southeastern end is 14 miles only from the Antigua bank, and the depth of water between the two is upwards of 122 fathoms (732 feet). An elevation of the Anguilla bank of about 40 fathoms (240 feet) would unite the Islands upon it.

The land shell fauna of the above named Islands is unquestionably the same; it has some alliance with that of Haiti, but very little with that of the Islands to the south of the Anguilla bank. Not only is the absence of certain genera prevailing in Sections I., II., and III. noticeable, but the diminished number of representatives of others is equally so, for example:

	in § I.	§ III.	§ IV.
Megalomastoma.....	13 species,	1	3
Alcacia.....	9	" 2	1
Strophia.....	27	" 2	2
Macroceramus.....	35	" 10	2
Cylindrella.....	93	" 28	6

The fact that *Megalomastoma*, *Alcacia*, *Strophia*, and *Macroceramus* are not represented in the Islands south of the Anguilla bank (§ V.) and that in those Islands there are 4 species only of *Cylindrella*, affords striking proof of the difference of their faunas.

St. Croix is not unfrequently classed with the Virgin Islands, from which it is 35 miles distant, but it stands on a bank disconnected from any others and with very deep water around it. Soundings are on record (taken, I believe, by Capt. Parsons, R. N.), between it and the Virgin bank, about the mid-channel, of 1,550 fathoms (9,300 feet), and not far from its northern shore of 2,000 fathoms (12,000 feet), without bottom being found.

The following soundings to the eastward were obtained by the U. S. S. Yantic, in 1870, between St. Thomas and Saba:

		fathoms.	feet.
N. Lat. 18° 01' 50".	W. Long. 64° 10' 20".	—1,825 =	10,950
" 17° 55' 00".	" 63° 50' 30".	—1,240 =	7,440

Considering the facts of distribution already given, and the above mentioned soundings, it seems highly probable that very deep water will be found between the Anguilla and Antigua banks.

In this connection it is interesting to notice that the depth of the sea is 1,376 fathoms (8,256 feet) between Cuba and Jamaica, in N. Lat. $18^{\circ} 36'$, W. Long. $76^{\circ} 03'$, a somewhat near approximation to the Latitude of the great depth between the Virgin bank (St. Thomas) and Saba.

The fauna of St. Croix is closely allied to that of Puerto Rico, and seeing the depth of water between them, it is a significant fact that *Caracolla* (*Helix*), *caracolla* L. one of the characteristic species of the latter, is found subfossil only, with other extinct species, and among them a *Strophia*, in the former. *Megalomastoma*, *Alcadia*, and *Macroceramus* do not exist in St. Croix, while there is one species of *Cylindrella*. With further reference to the soundings, the Latitude of Jamaica, and the nature of the fauna of St. Croix, I should mention that *Megalomastoma* and *Strophia* have none, and *Macroceramus* one representative (a Cuban species) in Jamaica, in which Island there are, however, 14 species of *Alcadia* and 51 of *Cylindrella*. Sombrero has one living species (*Chondropoma Julieni* Pf.) which is also found, with a *Strophia*, embedded in the phosphatic limestones of that Island.

Professor Cope lately referred to me, for determination, shells from the matrix between the femoral condyles of *Loxomylus latidens*, Cope, one of the great extinct Rodents, the bones of which have been found in the caves of Anguilla. The shells are closely allied to *Tudora pupaeformis*, Sow, now living on Anguilla, and apparently identical with an undetermined species which inhabits St. Martin.

SECTION V.—*Subdivision 1. Islands on the St. Christopher and Antigua banks, Montserrat, Guadeloupe, Dominica, Martinique, and Barbados*.*

Subdivision 2. St. Lucia, St. Vincent, Grenada and the Grenadines, Tobago, and Trinidad.

In former papers I did not treat the fauna of the Islands in this section as capable of subdivision, but with my present increased knowledge must necessarily do so.

Immediately to the south of the Anguilla bank there is, to the eastward, a bank on which stand Barbuda and Antigua, and to the westward, another (separated from the adjacent Islands by channels of a greater depth than 200 fathoms, 1,200 feet), which constitutes the base of St. Eustatius, St. Christopher, and Nevis. At a short distance from the northern end of the latter bank stands Saba (about $2\frac{1}{2}$ miles in diameter,) rising perpendicularly from the sea to the height of 2,820 feet, with the 100 fathoms (600 feet) line of soundings about half a mile from its western, and a little more than half that distance from its eastern side. Late soundings between St. Eustatius and Saba (Lat. $17^{\circ} 31' 10''$, Long. $63^{\circ} 08' 30''$) give a depth of 343 fathoms (2,058 feet).

* I omit mention of several small Islands geographically belonging to those enumerated in both subdivisions.

Within 3 miles S. W. from Saba is the Saba bank, which forms nearly a parallelogram, its longest sides about 32 miles and its shortest about 20 miles in extent, the eastern edge fringed with a narrow ledge of living coral, sand and rock, nearly 30 miles in length and varying in depth from $6\frac{1}{2}$ to 10 fathoms.

It is remarkable that an elevation similar to that mentioned with reference to the Virgin and Anguilla banks (less than 40 fathoms,) would unite Barbuda and Antigua, also St. Eustatius, St. Christopher and Nevis, and convert the Saba bank into an Island.

With respect to Guadeloupe, Dominica, Martinique, &c., the following particulars of soundings lately taken by the U. S. S. "Yantic," Commander Irwin, are extremely interesting :

Between			fathoms.	feet.
Antigua and Guadeloupe,	Lat. $16^{\circ} 40'$.	Long. $61^{\circ} 48'$.	348 =	2,088
Guadeloupe and Dominica,	" $15^{\circ} 45'$.	" $61^{\circ} 37'$.	850 =	2,700
Dominica and Martinique,	" $15^{\circ} 06'$.	" $61^{\circ} 20'$.	1,078 =	6,468
Martinique and St. Lucia,	" $14^{\circ} 17'$.	" $61^{\circ} 04'$.	1,232 =	7,392
St. Lucia and St. Vincent,	" $13^{\circ} 33'$.	" $61^{\circ} 20'$.	1,346 =	8,076

Capt. Parsons, R. N., found on a line of soundings from St. Vincent to Barbados, depths of 350, 956, 1,218 in (about) Lat. $13^{\circ} 05'$, Long. $60^{\circ} 25'$, 1,211, and 147 fathoms, the greatest ascertained depth being equal to 7,308 feet.

The same officer obtained the following results from soundings between Barbados and Tobago, viz. :

			fathoms.	feet.
N. Lat. $13^{\circ} 00'$.	W. Long. $59^{\circ} 40'$.		300 =	1,800
" $12^{\circ} 40'$.	" "		570 =	3,420
" $12^{\circ} 30'$.	" $59^{\circ} 50'$.		780 =	4,680
" $12^{\circ} 10'$.	" $60^{\circ} 05'$.		1,030 =	6,180
" $11^{\circ} 40'$.	" $60^{\circ} 10'$.		1,060 =	6,360
" $11^{\circ} 27'$.	" $60^{\circ} 25'$.		500 =	3,000 without bottom.

I have already given the depths between Martinique and St. Lucia, that Island and St. Vincent and the latter and Barbados. St. Vincent is separated from the northern end of the Grenada bank, on which Grenada and the Grenadines are situated, by a narrow channel, not over, Capt. Parsons remarks, 300 fathoms (1,800 feet) deep. The Grenadines consist of a chain of Islands and rocks extending for 60 miles between Grenada and St. Vincent. The depth found on soundings taken by the "Yantic," gave on and near to the west side of St. Vincent, in about the Latitude of its northern end, 1,080 fathoms (6480 feet), opposite the channel to the south of St. Vincent 594 fathoms (3,564 feet), and along the West side, in close proximity to the Grenada bank, from North to South, 880 fathoms (5,280 feet), 801 fathoms (4,806 feet), 916 fathoms (5,496 feet), and 545 fathoms (3,270 feet).

Trinidad and Tobago are on soundings (less than 100 fathoms), both being in fact on the submarine slope of the South American Continent, and the deeper water found by the "Yantic" between the former Island and the Grenada bank, in (about) Lat. $11^{\circ} 50'$, Long. $61^{\circ} 45'$, was 386

fathoms (2,316 feet), while the maximum depth known, as above stated, between Tobago and Barbados, is 1,060 fathoms (6,360 feet).

It appears from the foregoing evidence, that Trinidad, Tobago, the Grenada bank (an elevation of which to the extent of 40 fathoms would give an Island nearly 100 miles in length), and St. Vincent, stand on a partially submerged ridge, an extension of the South American Continent, having, say, 1,000 fathoms depth of water on the west side, and still greater depths between its northern termination and St. Lucia, also on its eastern side between it and Barbados, and between the latter Island and Tobago. The summit of this ridge is 2,316 feet beneath the level of the sea between Trinidad and the Grenada bank, and, say, 1,800 feet between that and St. Vincent, while the altitudes above the sea are, of Trinidad 3,100, Tobago 1,800, Grenada 2,746, and St. Vincent about 3,000 feet.

The genera and species of land Mollusks which occur in the Islands on the "submerged ridge" just mentioned (Trinidad to St. Lucia inclusive), are chiefly allied to those which are characteristic of Venezuela, the portion of the Continent contiguous to Trinidad. The species of *Helix*, in its wide application, including *Stenopus*, *Hyalina*, and *Zonites*, are 15 only in number, while there are of *Bulimus* (as restricted by Albers) 5, and of *Bulimulus* 14 species, the total number of species of the latter in the West Indies, being about 38. The subgenus *Dentellaria* (*Helix*) is characteristic of the Islands embraced in Subdivision 1 of Section V., but has few representatives in those named in Subdivision 2. *D. perplexa*, Fer., is peculiar to the Grenadines and Grenada, *D. Isabella*, Fer., is common to one of the Grenadines, Barbados, and Cayenne, (French Guiana,) and *D. orbiculata*, Fer., to St. Lucia, Martinique and Cayenne.

The genus *Bulimus*, of which the subgenera represented are *Borus*, *Pelecychilus*, and *Eurytus*, all South American, occurs in the West Indies only in the group (subdivision 2) embracing St. Lucia and Trinidad and the intermediate Islands. *Borus oblongus* inhabits Barbados, but it was introduced there from St. Vincent by the late Rev. Mr. Parkinson. *Eurytus aulacostylus*, Pf., occurs both in St. Lucia and Demerara. With respect to Trinidad, it is certainly curious that we have there a species of *Diplommatina* (*D. Huttoni*, Pf.) and of *Ennea* (*E. bicolor*, Hutton). the latter found also in Grenada and St. Thomas, both living in the East Indies. Guppy has lately discovered a species to which he has given the generic name of *Blandiella*, but it is, I think, a *Truncatella*, allied, at least, to the subgenus *Taheitia*, H. and A. Adams, the type of which is *T. porrecta*, Gould, of Tahiti.

The land shell fauna of the Islands in subdivision 2 have marked alliance with that of Cayenne. There are on that group six species of *Helix* which are also found in Cayenne, viz.: *Dentellaria orbiculata*, *nux-denticulata*, *dentiens*, *Isabella*, *badia*, and *Thelidomus discolor*. The genus *Cyclophorus* has no less than seven species in Martinique, Dominica, and Guadeloupe, but none in any other part of the West Indies, while one, a different species, inhabits Cayenne. In Barbados no member of the family Cyclostomacea has been discovered. I have already referred to some other peculiarities of this fauna as compared with that of the Islands

embraced in section IV, and should add that *Dentellaria* *does not* occur in those Islands. *Helix* predominates over *Bulimus* in North America and the Islands in Sections I., II., III., and IV, while the reverse is the case in South America, and there is at least an increased proportionate number of *Bulimus*, as compared with *Helix* in Section V.

I have spoken of a "ridge" on which the Islands in subdivision 2 of that section stand (St. Lucia excepted), and must remark in addition, that there may have existed an extension of the South American Continent, from the eastern boundary of Guiana to some point west of the Grenada bank, and running North to the neighborhood of the Anguilla bank, on the western side of which extension there was the fauna now to be studied in the Islands from St. Lucia to Trinidad, and on the eastern side, in those from the St. Christopher and Antigua banks to Barbados.

Reference has been made to the similarity of depths in nearly the same Latitude between Jamaica and Cuba, and Saba and the Virgin bank.

Mr. Rawson has directed my attention to a comparison of the following depths in the Caribbean sea, ascertained by soundings between Kingston (Jamaica *) and Chagres, and those between Barbados and Tobago :

Lat. $12^{\circ} 00'$, Long. $79^{\circ} 25'$ —924 fa. Lat. $12^{\circ} 10'$, Long. $60^{\circ} 05'$ —1,030 fa.
 " $11^{\circ} 25'$, " $79^{\circ} 30'$ —969 fa. " $11^{\circ} 40'$, " $60^{\circ} 10'$ —1,060 fa.

Taking a wide view of land shell distribution in the West Indies, it may be said that the fauna of the Islands on the northern side of the Caribbean sea, from Cuba to the Virgin and Anguilla banks, was derived from Mexico and Central America, and that of the Islands of the eastern side, from the Antigua and St. Christopher banks to Trinidad, from tropical South America. It is noticeable that the mountains in the former Islands, range, generally, from West to East, but in the latter from South to North, excepting in Tobago and Trinidad, where they are parallel with, or in the same direction as the coast mountains of the adjacent continent.

The present geological condition of the Islands affords ample evidence of the lapse of vast periods of time in the earlier tertiary epochs, during which the Limestone formations, extensively developed in most of the Islands, were deposited. The white Limestone of Jamaica, referred by Sawkins (Geology of Jamaica, London, 1869), to the Post Pliocene, covers more than three-fourths of the Island and is computed at 2000 feet in thickness. It rests on the yellow Limestone (Miocene), which, he remarks, during the deposition of the former, "sank to great depths, in some places apparently 3000 feet, so as to permit the growth of those great coral structures, from the débris of which the enormous calcareous development of the white Limestone has been derived. The lapse of time required for these important phenomena cannot be easily realized by the imagination."

That the Islands, or some of them, were formerly united and formed part of an ancient continent, may, it would seem for various reasons, be inferred, and the discovery of mammalian and other remains in Anguilla, Sombrero, etc., is an important one.

* The Pedro bank, within 50 miles of the southern shores of Jamaica, with an elevation of 30 to 40 fathoms would give an Island 100 miles long, 30 in breadth near its centre, and 45 at its western edge.

Referring to the Anguilla cave remains, Prof. Cope remarks (Proc. Acad. N. S. Phila., 1868) on their indicating "that the Caribbean continent had not been submerged prior to the close of the Post-pliocene, and that its connection was with the other Antilles, while a wide strait separated it from the then comparatively remote shores of North America."

The occurrence with the Anguilla fossils of a land shell of a species now living, points to the age of the existing fauna, but the marked difference, both generic and specific, between the present land shell fauna of the Islands upon and to the North and West of the Anguilla bank and those to the South of it, may be taken as evidence of their early and continued separation.

Captain Parsons, in MS. Notes on the Geology of some of the West Indies, for a perusal of which I am indebted to Mr. Rawson, observes that the eastern or windward edge of the Grenada bank is at an average distance of 7 miles from the Islands, while the western edge is not more than two-thirds of a mile, and that there is a similar great disparity in other of the banks and Islands. He concludes that such increased development of the eastern over the western sides is primarily due to the equatorial current, which running for ages through the Islands has brought and deposited material on the windward side.*

On this subject, the following quotation from "The Natural History of Barbadoes," by the Rev. W. Hughes, London, 1750, is really interesting, and particularly so in connection with the views of Sawkins with regard to Jamaica.

"The current of the Deluge between the Tropics ran from East to West. Notice the shattered condition of the eastward side of the chain of hills and cliffs, which are as barriers to the Island (Barbados), from Cuckold's Point to Conset's Bay, for as they face the East their torn state on that side alone and no where else, shews that they not only by their situation, first stemmed, but as they were higher than any other part of the Island, they wholly bore the repeated percussions of the current in the gradual ascent of the Deluge. Notice, also, the coping figure of the Island from East to West, for if we view narrowly the several gradual descents of so many continued ridges of rock, like cascades, descending precipitously to the westward (for instance, the long chain of hills from Mount Gilboa, in St. Lucia's Parish, to the Black Rock in St. Michael's), we shall conclude from the deep soil on the eastward of these where the land is level, and from the rugged and bare washed surface of the west, that the latter was thus torn by the violence of the waters falling over them, and the former, the effect of the subsided sediment upon the decrease of the Deluge. The want of such a bed of rocks from Black Rock to St. Anne's Castle caused the chasm which opens to the sea through Bridgetown opposite to the Valley of St. George's. The course of the gullies is, too, from East to West, and they were caused by the current of the Deluge, the regular course of which to the westward between the tropics was the natural consequence of the easterly trade wind."

* In the Bahamas the Islands are, generally speaking, on the windward side of their respective groups and banks.—(Nelson.)

Sawkins, in the Report on Jamaica, to which I have already referred, shows that the highest elevations on that Island are situated to the east, and the inclined slope rises from the west. With respect to this, he draws "deductions from two important elements:

"1. The great equatorial currents have existed in times past as at present.

"2. That the trade winds also prevailed with the same uniformity."

Referring to vestiges of volcanic action and certain stratified deposits towards the eastern end of the Island, containing pebbles and debris of previously existing rocks, Sawkins remarks: "This (volcanic) action might have operated intermittently, so as to permit the growth of coral reefs, marine animals, &c., of which the remains are contained in the limestone formations. Again, supposing the deposits to have originated from local igneous or volcanic action, or from debris derived from islands to the east, submersion having intervened, the lighter materials and finer sediment would be transported by the currents to the westward, these influences combining with subsequent changes of level, account for the prolongation of the land to the westward."

In connection with the facts stated I can only incidentally refer to the barrier presented by Trinidad, Tobago, the Grenada bank, and St. Vincent to the distribution, to the westward, of marine forms living at greater depths than 400 fathoms; and to the same barrier and others offered by the Islands and banks to the North of St. Vincent, to the flow of the equatorial current into the Caribbean sea. Also to the existence of a cold current at great depths between Barbados and Tobago, shown by the temperatures ascertained by Capt. Parsons, viz.:

Surface,	Max.	79°	Fah.,	at	1,030	fathoms,	Min.	38°
		"	82°	"	"	1,060	"	38°.5

Stated Meeting, March 17, 1871.

Present, seventeen members.

DR. WOOD, President, in the chair.

Photographs of Mr. Frederick Graff and Prof. D. F. Sandberger, of Würzburg, were received for the Album.

A letter of envoy was received from the Swedish Bureau of Statistics.

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